# GLACIAL AND POST-GLACIAL HISTORY OF THE HUDSON AND CHAMPLAIN VALLEYS. II.[1]

OUTLINE—*Concluded.*



[1] Continued from p. 469.

## HISTORY.

### HUDSON WATER BODY AND SUCCESSIVE POSITIONS OF THE ICE AS IT RETREATED THROUGH THE HUDSON VALLEY.

As THE ice retired from the Brooklyn-Perth Amboy moraine northward, it halted for a greater or less time at the successive positions which are marked on the higher lands by belts of thick drift, with more or less distinct morainic topography, by elongate kame areas with the aspect of moraines, often bordered by plains of gravel and sand having the form of overwash or outwash plains, or by aggradation plains without moraine or kame areas at their source. On Staten Island possibly one morainic belt of limited extent, and on Long Island at least two and probably three such morainic belts, mark some of the halting-places of the ice, north of the main moraine. On the Triassic lowlands in New Jersey, no less than seven such positions are marked by belts of thick drift with either the moraine or kame aspect. (See Fig. 8, p. 427.) In the lower ground, both in the lowland west of the Palisade Ridge and in the Hudson Valley, the ice and the ice-waters discharged into a standing body of water. In the low ground, west of the Palisade Ridge, the deposits of the ice-waters are marked by the complex series of sand- and gravel-

plains or plateaus, some of them heading in kames and others with ice-molded but kameless sources, which is found from the latitude of Hackensack and Englewood nearly to the northern border of the state. The deposits of the ice-waters are also marked by the clay which is found underneath the gravel and sand in the southern part of these lowlands, or spread out with little overlying sand or gravel, and which has thicknesses from 100 feet or less, to 215 feet.[1]

That the water body in which these deposits accumulated may have been separated from, and perhaps was slightly higher than the Hudson water body will be shown later (p. 645). It is to be noted that the accumulations marking the successive positions of the ice-edge on the higher land are not traceable across the lowlands occupied by this water body, at least not to the same extent, either in number or continuity, as on the higher land.

In the Hudson Valley the deposits marking the successive positions of the ice-edge do not have notable development south of Sing Sing, but from a little north of this place to north of Glens Falls, and beyond into the Champlain Valley, there is a succession of deposits, described above (pp. 430 ff.), which, it is believed, mark its successive positions. As the ice retreated northward, the ice-front appears to have assumed two distinct phases in different parts of the valley.

*Phase 1.*—In those parts of the valley (notably the narrower parts) where the gravel plateaus are marked either by morainic phenomena or by irregularities of similar import at the edge next to the Hudson, or by higher elevation next to the Hudson and lower next to the valley wall, and with layers dipping toward the valley wall and southward, it is believed that the ice protruded down the valley, and that the accumulations took place at the edge of this ice-tongue, or between

[1] See *Annual Report* of the State Geologist of New Jersey for 1903, pp. 195–210, and *Final Report*, Vol. V, pp. 506–13, 595–628, 632–42. At the time this report was written three hypotheses were suggested to explain the form of these higher gravel plains and plateaus; namely, (1) that they were accumulated in a water body, either a lake or an arm of the sea; (2) that they had received their form from stagnant ice-masses; (3) that both co-operated. In the absence of wave-wrought features, and in the absence of exposures, the junior author preferred to leave open the question of the origin of these features, where the structure was unknown, although at this time, and for some time before, it had been recognized that a water body existed in the Hudson Valley as the ice was retiring, and that both ice and water body had been influential in producing the forms there found.

the ice-tongue and the valley wall. Such deposits, it is believed, are represented (1) by the terrace south of the Croton River mouth (Fig. 9, No. 20, p. 429); (2) by the moraine on the north slope of the Palisade Ridge, which has not the accompanying gravel plateau (Fig. 9, No. 15); (3) by the Jones Point gravel plateau (Fig. 9, No. 19); (4) by Roye Hook (Fig. 9, No. 29), and possibly that part of the State Camp plateau which appears to slope eastward. In some places where tributary streams head northward the ice occupied the upper portion of the tributary valley at the same time that the ice-tongue existed in the main Hudson near its mouth, so that deposits with layers dipping toward the valley wall contributed from the ice-tongue in the Hudson Valley, occur side by side with deposits from the tributary streams of ice-water which show layers dipping toward the Hudson. The main part of the State Camp plateau, which appears to have been built of materials brought by streams of ice-water down the valley of the Peekskill and its tributaries, is thought to be an example. Other phenomena which indicate the presence of the ice in the valley, against which stratified drift was accumulating at higher levels, but to which this valley ice was not active in contributing, it is thought, may be represented by the deposits at Carthage Landing and Low Point (Fig. 9, No. 44), and at New Hamburg (Fig. 9, No. 46). At the latter place, however, the waters from the ice in the valley may have been active contributors in building the plateau, at least in its early stages. (5) The West Point gravel plateau, and probably the Cold Spring kames and the Cold Spring-Garrisons terrace (Fig. 9, Nos. 31, 33) also represent deposits made at the edge of a tongue of ice which occupied the valley.

*Phase 2.*—The second phase of the ice-front is represented in the broader parts of the lower Hudson and in the broad upper Hudson where the gravel plateaus are marked by moraines or kames or undulatory topography of similar import, at the margin toward the valley walls, and by the smoother surface and steep outer face toward the Hudson, together with the dip of the layers generally away from the valley wall, and the gradation of the materials down the dip from coarse gravel into sand and finally into clay. This clay spreads out in the upper Hudson as a wide plain, rising gradually from the present Hudson River bluffs toward the gravel plateaus and the valley

walls. In these parts of the Hudson it is believed that an embayment in the ice-front existed in the deeper water over the lower parts of the plain, and that the ice-edge is marked (1) by the series of gravel plateaus with the characters above mentioned at their upper margin; (2) by the kames fronted by clay-plains without intervening gravel plateaus; and (3) by the series of elongate depressions like those between the plateaus of the series south of Saratoga Springs now occupied in part by lakes, such as Round Lake and Saratoga Lake, Lonely Lake, and perhaps also Ballston Lake.[1]

Such a form of the ice-front is marked, it is believed, by the deposits (1) at Croton and Croton Landing, and at Haverstraw and North Haverstraw (Fig. 9, Nos. 22, 15, and 17); (2) at Newburg-New Windsor, and Fishkill-Dutchess Junction (Fig. 9, Nos. 37, 38, and 42, 41). Other places where the ice halted are marked (1) by the South Schodack gravel plateau (Fig. 13, No. 73, p. 436) and the line of kames extending northwest of East Greenbush (Fig. 13, No. 74), by kames near Teller Hill, and the line extending through North Albany to Newtonville (Fig. 13, No. 65), (2) by the South Bethlehem gravel plateau (Fig. 13, No. 62); (3) by kames near New Scotland and Voorheesville (Fig. 13, Nos. 63 and 64); (4) by the Troy gravel plateau and kames (Fig. 13, No. 76); (5) by the series of gravel plateaus separated by elongate depressions, south of Saratoga Springs, where several successive positions of the ice-edge are marked; (6) by the succession of kames and gravel plateaus near Glens Falls, where several positions of the ice-edge are marked (Fig. 13, No. 85, and Fig. 18, west of No. 86, and Nos. 87 to 89, p. 454). This includes the Glen Lake kame area north of Glens Falls.

The depth of water into which the ice flowed and built up kame areas and similar deposits appears in places to have been considerable, as much as 60 to 80, or possibly 100 feet, if the evidence furnished by the Teller Hill kames, southeast of Albany (elevation of top, 280 feet) and the adjacent South Schodack-East Greenbush gravel plateau (elevation, 340–360 feet) be correctly interpreted. The 260–280-foot Lonely Lake gravel plateau (Fig. 13, No. 83) was built in water

[1] The writer does not mean to imply here that the plateaus between these depressions were built only from successive positions marked by the depressions, for probably the building was in process during the retreat from one depression to the next succeeding.

which was 100 feet deep over the plateau, if the adjacent plateaus be correctly interpreted. These figures are in accord with those showing the depth of water in which the ice succeeded in making a subdued moraine in the basin of Lake Passaic. They do not show the total depth of water in the water body, but the depth only in which the ice was able to build the moraine, kames, etc., mentioned. If the proportion of ice to débris carried were known, it would furnish a means of estimating the thickness of the ice on these moraines and kames.

In the Hudson Valley no less than fifteen halting-places are thus indicated, and of these at least six are marked by distinct morainic phenomena. This does not take account of the area between Poughkeepsie and Catskill, which was observed only in transit.

### SUCCESSIVE POSITIONS OF THE ICE-EDGE IN THE PASSAGES FROM HUDSON TO CHAMPLAIN VALLEY.

The successive positions of the ice as it retreated from the Hudson Valley into the Lake Champlain region are not known. In the western or Lake George passage, after having built the Glen Lake-Hopkins Pond kame area (Fig. 18, Nos. 87–89), thus forming the dam that blocks the valley and makes the basin in which southern Lake George is situated, the ice is not known to have made notable deposits until the northern end of Lake George is reached, where the western passage opens out into the Lake Champlain Valley. In the eastern passage the successive positions of the ice-edge are not known. It seems probable, however, that the ice-front had a direction such that local lakes were formed in tributary valleys in which clays similar to those of the Hudson and Champlain regions were deposited, but at levels higher than those reached by the Hudson water body.

### SUCCESSIVE POSITIONS OF ICE-EDGE IN CHAMPLAIN VALLEY.

The successive positions of the ice in the Lake Champlain Valley are not well known. Some of its positions are marked by the terraces: (1) at Baldwin and northward (Fig. 18, No. 105, *A*, p. 455); (2) at Street Road (Fig. 18, No. 107) and northward; (3) by the moraine northwest of Crown Point (Fig. 18, northwest of No. 108); (4) by limited gravel areas along the mountain-side from Port Henry

to Westport; (5) by the Bouquet River high-level delta; (6) by the Reber and Towers Forge gravel plateaus or deltas on the North Branch of the Bouquet River; (7) by the moraine or series of moraines along the higher land between Harkness and Schuyler's Falls, and at Cadyville and west toward Dannemorra; (8) by the Saranac high-level gravel plateau; (9) by kames or moraine west by south of West Chazy.

HUDSON-CHAMPLAIN WATER BODY.

When the ice had retreated into the Champlain Valley, the Hudson water body occupied the lowland between the Hudson and the Lake Champlain Valley also, and may now be conveniently referred to as the Hudson-Champlain water body (see Fig. 22).[1] The successive positions of the ice as it retreated up the Champlain Valley are known to the writer at a few points only, and these are on the west side of the valley. The moraines found above the highest level reached by the water body near Crown Point, and at the various places indicated in the detailed description above (pp. 462, 463), between Harkness Station and Cadyville, and west of the latter place toward Dannemorra, all indicate a general north-south and northeast-southwest direction of the ice-front, and also indicate that the ice was in the lower land and its edge was on the slopes of the higher land. This appears likewise to have been true when the Baldwin and Street Road plateaus were built. Where the ice-edge and the body of ice were at Crown Point when the highest deposits of lacustrine origin were deposited is not known, although doubtless, it could be determined by detailed investigation. It seems difficult to reconcile the eastward dip of the stratified drift built out in the water body with the position of the body of the ice in the lowlands when the moraine higher on the mountain-side was built. The deltas, both on the main Bouquet River and on the north branch, are so situated that neither the assumption of an embayment in the ice-front nor a protruding tongue of ice down the Champlain Valley is necessary to explain the phenomena. The deposits of gravel at 580 feet on the Ausable may be interpreted

[1] This name was first given to the water body occupying the Hudson and Champlain Valleys by MR. WARREN UPHAM, who published on this subject in 1891 in the *Bulletin of the Geological Society of America*, Vol. III, pp. 484–87, and in the *American Journal of Science*, Vol. CXXIX (1895), pp. 13 ff.

FIG. 22.

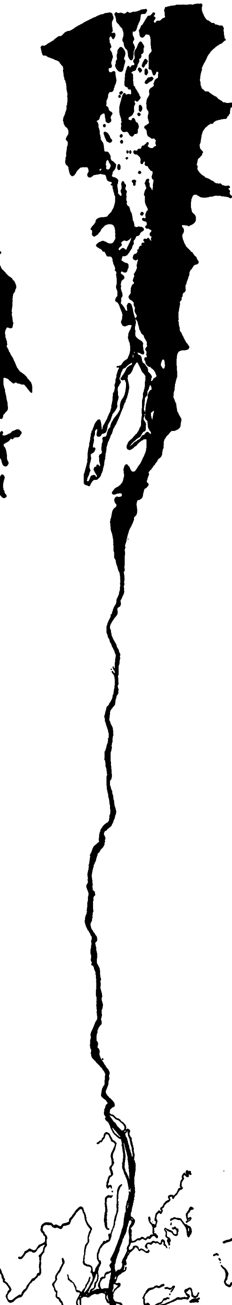

FIG. 23.

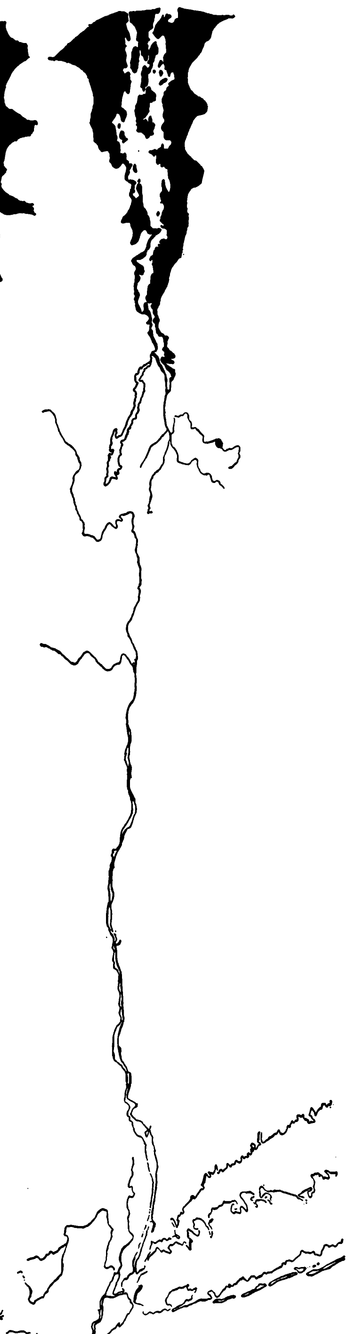

FIG. 24.

FIG. 22.—Approximate area once covered by the Hudson-Champlain water body on the assumption that it was a lake. The outline does not include the highest levels reached as the ice was retreating from the Brooklyn-Perth Amboy moraine to Kill van Kull, nor does it include the extension of the area into Long Island Sound.

FIG. 23.—Approximate area once covered by Higher Glacial Lake Champlain. No attempt is made to show the northern limit.

FIG. 24.—Approximate area covered by " Marine " Champlain. No attempt is made to show

with either form of front. The highest Saranac gravel plateau indicates the presence of the ice at its northern margin, and possibly some of the phenomena of the western margin indicate its presence there, but this plateau is not well known. It will be referred to again.

On the whole, then, the moraines of the west side of the Champlain Valley, at high levels, indicate a retreat of the ice with a general north-south or northeast-southwest front, and with the body of the ice in the valley. At lower levels, in general, no embayment in the ice-front seems to be required by the gravel plateaus, although deposition of some of the stratified drift in the water body is difficult to understand if the ice occupied the lowlands, and there was no embayment. The high-level Saranac gravel plateau or delta is probably an example. It seems necessary to believe that when the moraines at high levels near Harkness and west of Cadyville were being built local lakes existed at the front of the ice in the valleys of streams now flowing into Lake Champlain, at levels higher than the level of the water body in the Champlain Valley.

## HIGHER GLACIAL LAKE CHAMPLAIN.

As the ice retreated through the Champlain Valley, an uplift took place at the south which separated the water body in this valley from the Hudson water body south of Fort Edward and inaugurated the history of a water body which Baldwin first named Glacial Lake Champlain. In view of the fact that another glacial lake may be represented by the upper part of the lower series of terraces, it seems best to call it Higher Glacial Lake Champlain. This lake drained southward through the Fort Edward Valley and across the barrier south of Fort Edward. Whether the Hudson water body continued to exist for any length of time after the inauguration of Higher Glacial Lake Champlain is not known. Indeed, it is not known that its disappearance may not have been on the appearance of Higher Glacial Lake Champlain. By this time, or earlier, those peculiar conditions which it appears had existed through much of the history of the Hudson water body, and had prevented the making of distinct wave-wrought features, ceased to be effective, and the upper series of wave-wrought features, which may be seen from Street Road north,

was made. Contemporaneously with at least the lower terraces of this upper series, the Fort Edward outlet valley was eroded. The question as to where the ice-edge was when Higher Glacial Lake Champlain was inaugurated will be referred to presently, as will also the greater range of the upper series of wave-wrought features from Street Road to north of Crown Point. When the lowest terrace of the upper series was made, the water-level remained constant long enough for a delta to be built on a number of the northern streams. These deltas are capable of another interpretation, however, as will be seen later.

## LAKE ST. LAWRENCE.

After the upper series of terraces had been completed, the Fort Edward outlet was abandoned, and the water-level fell rapidly to the upper terrace of the lower series. Whether this level was the sea-level or not seems uncertain. The level of the marine fossils falls below it 70–80 feet at the north, and not far from that amount at the south, so far as the writer has been able to discover.[1] If this water-level, represented by the upper terrace of the lower series, was not the sea-level, then it represents a lake-level made by the opening up of some outlet, presumably toward the St. Lawrence, which was lower than the Fort Edward outlet. The location of such an outlet is entirely unknown, and its existence is hypothetical. In 1895 Mr. Warren Upham suggested such a lake "occupying an area from Lake Ontario to near Quebec," and "dating from the confluence of Lakes Iroquois and Hudson-Champlain." Concerning it he says:

> From the time of union of Lakes Iroquois and Hudson-Champlain a strait at first about 150 feet deep, but later probably diminishing on account of the rise of the land about 50 feet, joined the broad exposure of water in the Ontario basin with the larger expanse in the St. Lawrence and Ottawa valleys and the basin of Lake Champlain. At the subsequent time of ingress of the sea past Quebec the level of Lake St. Lawrence fell probably 50 feet or less to the ocean level. The place of the glacial lake so far west as the Thousand Islands was then taken by the sea.

As thus defined, Lake St. Lawrence would fall in with the non-fossiliferous part of the lower series of terraces in the Champlain region. It is to be noted, however, that these terraces do not belong

[1] If fossils occur up to 250 feet, south of Vergennes, as reported by early investigators, the above does not hold.

to the Hudson-Champlain water body, nor even to the Higher Glacial Lake Champlain water body, but were made after the abandonment of the Fort Edward outlet. In 1903 Mr. Upham referred the low-level delta of the Hudson at Fort Edward and certain high-level terraces in Chesterfield in the Champlain region to Lake St. Lawrence. As will be seen from the foregoing account of the history of this region, the present writer considers this low-level delta at Fort Edward as having been made either in the latest stage of the Hudson-Champlain water body or in the earliest stage of Higher Glacial Lake Champlain, and the high-level terraces in the northern part of the Champlain region as having been made in Higher Glacial Lake Champlain. If the non-fossiliferous levels in the lower series of terraces in the Lake Champlain region be referred to Lake St. Lawrence, the Fort Edward delta and the high-level terraces in the northern Lake Champlain region cannot be so referred. Since it is doubtful if the water body in which either the high-level terraces or the Fort Edward delta were made reached to the St. Lawrence, it would seem to be inappropriate to call it Lake St. Lawrence. Altogether it seems best to reserve this name for the hypothetical lake which followed the union of the water bodies in the Ontario and Lake Champlain regions, as originally defined by Upham.

### MARINE CHAMPLAIN.

If the upper terrace of the lower series represents the sea-level, then, on the abandonment of the Fort Edward outlet, the history of the Higher Glacial Lake Champlain was closed and that of Marine Champlain was inaugurated. If during the fall of Higher Glacial Lake Champlain level to the upper terrace of the lower series there was no change in the altitude of the land, then, since the difference in level between the two series is generally 120 feet, Higher Glacial Lake Champlain must have been at its closing stage 120 feet above sea-level, and at its higher stage, barring uplift during its history, it must have been at least 75–100 feet higher. If the upper terrace of the lower series of terraces does not represent the sea-level, but does represent a lake-level, then Higher Glacial Lake Champlain was more than 120 feet A. T. when its outlet was abandoned. It is to be noted that the level of the Fort Edward outlet valley at White-

hall is close to 120 feet A. T., and if Higher Glacial Lake Champlain at the close of its history was 120 feet above sea-level, then there has been no change in level in this part of the outlet since that time, but farther south, at the 160-foot divide near Fort Edward, there has been an uplift of more than 40 feet.

During Marine Champlain time the lower series of terraces was made in the Champlain region from the uppermost marine level down to near the present Lake Champlain levels. Since the uppermost terrace of the lower series, when projected southward, falls below the Fort Edward outlet level, and since marine fossils have not been found south of Port Henry, where they were found at a level of 140 feet and lower, it is believed that the sea did not reach south as far as the Hudson Valley. It has been calculated, by projecting the terrace gradient southward, that Benson Landing or Putnam Station was approximately the southern limit reached by the waters forming the upper terrace of the lower series. During the time in which the lower series of terraces was being made, which it will be convenient to refer to as "Marine" Champlain[1] time, uplift was taking place, greater at the north than at the south, thus producing a wider range of the lower series of terraces at the north than at the south.

### EXTENDED COURSE OF POULTNEY-METTAWEE RIVER.

While the waters of the south end of "Marine" Champlain were receding northward on account of the uplift of the land, or at first on account of the cutting of the outlet of Lake St. Lawrence, if "Marine" Champlain includes lake terraces, and later on account of the uplift of the land, the streams which had flowed into Higher Glacial Lake Champlain, and which, because of the sudden fall of its water-level, had extended their courses across the old lake-floor plain to the new shore, finally were extending their courses across the old sea-floor to the receding shore. This was true of the Poultney and Mettawee Rivers, which during Hudson-Champlain and Higher Glacial Lake Champlain time debouched into that water body by independent mouths (see Fig. 25, *A*). On the fall of Higher Glacial Lake Champlain to "Marine" Champlain they became united and with other formerly independent

[1] "Marine" Champlain levels would thus include both those of the hypothetical Lake St. Lawrence and the levels marked by marine fossils, which are called Marine Champlain levels (without the quotation marks).

streams extended their courses across the newly exposed lake-floor from near Whitehall to the new water-level, which was, perhaps, somewhere near Putnam Station. The main stream of these united streams is referred to as the Poultney-Mettawee River (see Fig. 25, *B*). As the "marine" water body gradually withdrew, this stream extended its course to the new levels, and finally at the close of Marine Champlain time, on the inauguration of present Lake Champlain, it had its mouth some five miles northeast of Port Henry (Fig. 25, *C*, E) where, apparently, it built out a delta which is now about 23–51

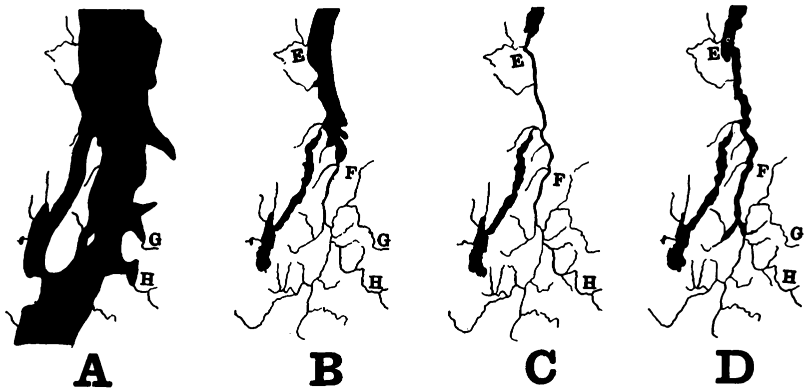


FIG. 25.—Changes in the Poultney-Mettawee River System.

*A*, the system dissevered in Hudson-Champlain time; *B*, the united and extended courses of the Poultney and Mettawee Rivers and their tributaries at the beginning of "Marine" Champlain time; *C*, the same at the close of "Marine" Champlain time or on the inauguration of present Lake Champlain; *D*, the Poultney-Mettawee system dissevered by the tipping of the water of Lake Champlain into the southern end of its basin caused by differential northern uplift; *E*, Port Henry; *F*, Benson Landing and Putnam Station; *G*, Poultney River; *H*, Mettawee River.

feet above sea-level or 50–78 feet below lake-level (Fig. 20, p. 467). During "Marine" Champlain time this stream cut out the channel in the clay plain described above (pp. 466–68) fromWhitehall to Benson Landing and northward to beyond Port Henry. Deposits made by the stream at successive positions of its advancing terminus, other than the submerged delta, have not been recognized, but they are in large part beneath the waters of the lake. The earlier deposits, however, should be found at low levels north of Benson Landing.

### INAUGURATION OF PRESENT LAKE CHAMPLAIN.

The emergence from the sea of the barrier which makes present Lake Champlain, closed Marine Champlain history and inaugurated

present Lake Champlain. By greater northern uplift Lake Champlain has been warped into the southern part of its basin, thus submerging the lower Poultney-Mettawee Valley, dissevering its system, and drowning the lower courses of its tributaries, including the South Bay Creek, and numerous other streams in southern Champlain (see Fig. 25, *D*, Fig. 20, and Fig. 21).

The streams in northern Champlain did not have their courses extended because of the uplift, for the outlet at the north controlled the water-level. Their courses have been extended only by the lowering of the water-level because of the cutting down of the outlet—an amount which Baldwin[1] has placed at 50 feet, but concerning which the writer has made no observations. Terraces lower than those of Marine Champlain have been made in present Lake Champlain and exposed to view by the lowering of the water-level due to the cutting of the outlet.

With this uplift, greater at the north than at the south, came the revival of north-heading streams and the arrest in the development of south-heading streams—a process which seems, from the topographic maps, to be well shown by East Creek, and by Dead Creek and its south-heading tributaries. Revival seems to be shown by the north-heading tributaries of Dead Creek.

The rapid down-cutting of the Poultney-Mettawee River, because of its steep northward gradient (120 feet in 14 miles, if the estimates of elevations at the close of Marine Champlain time be correct) surpassed that of most of its tributaries, which had neither the advantage of the steep northward gradient (since most of them had either an eastward or westward flow), nor had they the advantage of the volume of water of the larger stream. Consequently these tributaries were left to descend over steep slopes into the valley of the main stream (see Fig. 16, *A*, p. 452). The larger tributaries have been able to push this steep part of their gradient farther back from the main stream than the smaller ones. South-heading tributaries, with the advantage of the steep gradient given by the attitude of the land when the Poultney-Mettawee was cutting its channel, were more successful in keeping pace with the cutting of their mains, but since the northern uplift they have been arrested in the continuance

[1] *American Geologist*, Vol. XIII (1894), p. 104.

of this work, while north-heading tributaries have been given the advantage. It is believed that on some of the streams this record can be read from the topographic maps.

### HISTORY IN HUDSON VALLEY IN HIGHER GLACIAL LAKE CHAMPLAIN TIME AND LATER.

The history of the Hudson Valley has been left at the point where the southern uplift brought a barrier south of Fort Edward into effective position and inaugurated Higher Glacial Lake Champlain (see Fig. 23). How long the Hudson water body survived is not known. It is not known, indeed, that its history overlaps to any extent the history of Higher Glacial Lake Champlain. The uplift which produced the latter may have been the final cause for the disappearance of the former. If the Hudson water body survived long after the inauguration of Higher Glacial Lake Champlain, then deposits made by the outlet stream from that lake would be expected at the point where it debouched into the Hudson water body. They may be present, but the region where they would be expected has not been studied enough to determine this point. Some stages in the lowering of the Hudson water body are represented by the low-level deltas mentioned at South Bethlehem, on the Hoosick River, on the Batten Kill, on the Hudson River, and possibly on other streams. It is a question whether any of these fall within Higher Glacial Lake Champlain time. Possibly the 280–300-foot Hudson River delta between Glens Falls and Fort Edward does. If neither this nor the Oniskethau low-level delta at South Bethlehem falls within that time, then certainly the Hudson water body had been reduced to a very shallow representative of its former extent, for the latter delta is only 20–40 feet higher than the lowest part of the floor opposite this place.

Whatever may have been the history soon after the inauguration of Higher Glacial Lake Champlain, it is certain that long before the close of that history the Hudson water body had disappeared, and that the outlet stream of Higher Glacial Lake Champlain, the greater part of which flowed through the present Hudson River valley (see Fig. 23), had taken its course across the old floor of the Hudson water body, that the streams which had debouched into the

Hudson water body had extended their courses across its old floor to the main stream flowing through the bottom of the trough made by the meeting of the slopes of the old floor. Into this old floor the outlet stream of Higher Glacial Lake Champlain trenched its course at a rate so rapid that the tributary streams were unable to keep pace with it, and they were thus made to descend to their main over steep slopes, which the small streams have not yet succeeded in pushing back far from the present Hudson bluffs (see Fig. 16, *A*).

Where the mouth of the Hudson was at this time is a subject for discussion, but it is certain that the land was higher than now and that the Hudson, at least in those regions where it is bordered by clay plain, cut its channel to depths now covered by the waters of the Hudson estuary 10–50 feet deep north of Catskill. Just how deep the cutting of this channel in the lower Hudson was during Higher Glacial Lake Champlain time is a matter of less certainty for two reasons: First, because there has been subsequent filling, as shown by at least 25 feet of clay at Croton, which contains "flags" and shells, while the clay below does not contain them, as reported by the dredgers excavating clay from the river for brick-making; second, because of the occurrence of certain "deeps," the origin of which is a matter of discussion. Such deeps are the New Hamburg "deep" (120 feet), the West Point deep (216 feet), Stony Point-Verplanck's Point deep (102 feet), Fort Washington deep (155 feet), and others. These deeps may be due either to scouring[1] by the Hudson during Higher Glacial Lake Champlain time or by the tide since then, or they were original depressions bridged by buried masses of stagnant ice over which the large amount of clay eroded from the upper Hudson during Higher Glacial Lake Champlain time was carried to the sea. If such ice-bridges existed, the deposition of materials carried by the waters of the stream would not be necessary. Subsequent melting of the ice would leave the "deeps."

While the origin of these deeps is open to discussion, on the whole it seems certain that the Hudson had cut its channel to a considerable depth below present sea-level before the close of Higher Glacial Lake Champlain time. This necessitates an altitude of the land at that time higher by the amount of the general cutting, at least.

[1] For ability of a stream to scour its channel below sea-level see CHAMBERLIN AND SALISBURY'S *Geology*, Vol. I, pp. 162 and 184.

In the process of down-cutting the river terraces which occur in the upper Hudson and on the tributary streams in both upper and lower Hudson, were made. Some river terraces had also been made in the tributary valleys before the close of the history of the Hudson water body.

Before the close of Higher Glacial Lake Champlain history, it is believed, the depression which has drowned the lower Hudson and its tributaries had begun. The basis of this belief is the amount of filling of the southern Hudson since the submergence. While this is a matter subject to revision on more accurate knowledge, calculations made indicate that the contributions of the Hudson and its tributaries since the submergence would be inadequate to furnish the material for this filling, and therefore that some of it was supplied by the cutting of the trench in the old lake-floor or old sea-floor in the northern Hudson Valley, before the Fort Edward outlet was abandoned.

### POST-HUDSON-CHAMPLAIN CHANGES OF DRAINAGE IN THE HUDSON VALLEY.

By the close of Higher Glacial Lake Champlain history nearly all the cutting by the Hudson south of Fort Edward had been accomplished. This is shown by the fact that the Fort Edward outlet floor is within less than 20 feet of the present Hudson level.

Aside from the trenching of the consequent courses of the streams below the floor of the Hudson water body, the pushing back of the steep gradients from the neighborhood of the Hudson River bluffs, and the development of subsequent tributaries on the consequent streams, a part of which at least was accomplished in Higher Glacial Lake Champlain time, there have been few changes in the valleys of the small streams since the disappearance of the Hudson water body. Depression of the land, part of which probably took place before the close of Higher Glacial Lake Champlain time, has drowned the lower courses of many tributaries from Troy south, and gravel has been carried out from the higher land into the trenches in the clay, making, in some cases, a gravel-floor, and in others, by further erosion, a gravel-floor and gravel-capped clay terraces, as on the Oniskethau. In a few places it seems likely that readjustments in drainage have taken

place because of the competition of neighboring streams. This seems to be true of the relations between Drummond Creek, a tributary of Saratoga Lake, and Outlet Creek, the outlet of Ballston Lake, which flows into Round Lake from the west (see Fig. 26).

*Piracy of Outlet Creek and beheading of Drummond Creek.*—Drummond Creek flows northeastward into Saratoga Lake through a rather broad, flat-bottomed valley, which is the northeastern part of one of the depressions between gravel plateaus south of Saratoga. Although this depression extends southwest beyond Ballston Lake, its southwestern part, including Ballston Lake, is not drained through Drummond Creek, but by a stream called Outlet Creek, flowing from Ballston Lake northeastward to a point a little over a mile from the lake near a place named East Line, where it makes a sharp turn southeastward and descends through a narrow, steep-sided valley with a high gradient to Round Lake (188 feet in altitude). At the point where Outlet Creek makes its southeastward turn its floor is something less than 280 feet in altitude. The question whether Drummond Creek has been beheaded by the working back of Outlet Creek, which tapped it and thus diverted its waters into Round Lake, would seem to rest upon the question whether Ballston Lake, which is now 285 feet above the sea, was ever enough higher to drain over the divide at 300 feet, down Drummond Creek into Saratoga Lake.

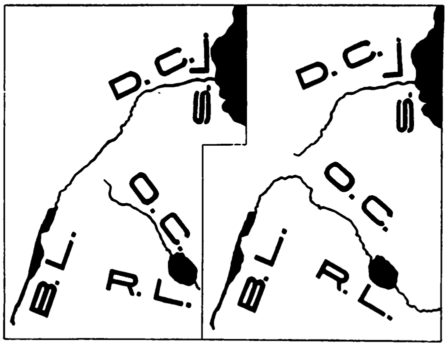


FIG. 26.—Piracy of Outlet Creek.

O. C.=Outlet Creek; D. C.=Drummond Creek; B. L.=Ballston Lake; R. L.=Round Lake; S. L.=Saratoga Lake.

### CORRELATION OF TERRACES IN THE CHAMPLAIN VALLEY WITH THOSE IN THE HUDSON VALLEY.

In the description of the wave-wrought terraces of the Lake Champlain region mention was made of the fact that in the upper series of terraces there is a range from the highest to the lowest of

about 200–220 feet at Street Road and Crown Point. This great range extends north of the latter point, but not so far north as the Bouquet River. From this river northward the range is from 75 to 100 feet, apparently increasing from south to north. The question arises at once: What is the explanation of the greater range of wave-wrought features at Street Road and Crown Point? Were they produced wholly in Higher Glacial Lake Champlain, or are part of them due to wave-action in the preceding Hudson-Champlain water body before the inauguration of Higher Glacial Lake Champlain? The decision of these questions depends on the correlation of the terraces in the Champlain Valley and the water-levels represented in the Hudson Valley. Since terraces have not been found in the narrow east and west passages which would connect the levels in the Hudson and Champlain regions, the possible correlation of the terraces in these regions must be covered by a series of assumptions which shall include the range of probable fact.

*First assumption.*—If the making of the gravel plateaus at Street Road and Crown Point be correlated with the emergence of the barrier at the south of the Fort Edward outlet, then the wave-wrought terraces of the upper series all fall within the history of Higher Glacial Lake Champlain and the greater range here might be due to the cutting down of the outlet and consequent fall of water-level, before the ice had retired far enough north to permit the making of these terraces in the northern Champlain valley. If this be the true explanation, it would require a total cutting of the Fort Edward outlet of 200–220 feet, during Higher Glacial Lake Champlain history, which is greater by 60–80 feet than any possible barrier which the present topography will permit. The second hypothesis to account for the greater range of wave-wrought terraces in southern Champlain, on the assumption that they were all made in the Higher Glacial Lake Champlain water body, is that during the history of this water body there were not only the conditions mentioned in hypothesis 1, but there was also a warping upward of this particular portion of the basin, in excess of the up-warping at the outlet, so as to produce the extra spread of terraces. On the most favorable assumption as to the original height of the barrier south of Fort Edward, this would require no less than 60–80 feet of up-warping at Street Road and Crown Point in excess of that at the outlet.

The emergence of the barrier assumed in this correlation requires a fall of the Hudson-Champlain water-level of 120 to 160 feet, while the ice was retiring from the neighborhood of the barrier south of Fort Edward to Street Road and Crown Point. If the Hudson-Champlain water body was an arm of the sea, this fall of water-level was due to uplift. The time necessary to produce this uplift was sufficient to permit the making of at least one secondary delta near Glens Falls on the Hudson—the 340-foot delta, and perhaps a second—the 280–300-foot delta east of the latter (see Fig. 18, p. 455). It is possible, however, that the 280–300-foot delta was made in the Higher Glacial Lake Champlain water body. It is a question whether this length of time was not more than that required for the ice to retreat to Street Road and Crown Point, and to make any deposits that are known between the deposits in the vicinity of Glens Falls and these points. If the time for the ice to retreat from its position near Glens Falls to Street Road is indicated by the time necessary to make the two secondary deltas of the Hudson River, it would seem that the ice retreat was excessively slow. If, on the other hand, the rate of retreat was similar to that in the lower Hudson, it would seem that the rate of uplift was excessive. There are, however, some indications that the history between the making of the glacial deposits in the vicinity of Glens Falls and those at Street Road and Crown Point was somewhat complicated, and, if so, there may have been time for the uplift mentioned during this history. If the Hudson-Champlain water body was a lake, the fall of the water-level which preceded the emergence of the barrier south of Fort Edward was in part due to the cutting of the Brooklyn Narrows outlet. The full amount of the cutting of this outlet, so far as known, is only 122 feet. If this be distributed among the sixteen or more halting-places between Brooklyn and Street Road, it would produce but a few feet of fall during the time of the retreat of the ice from the barrier south of Fort Edward to Street Road and Crown Point. Even if allowance be made for the increase in rate of cutting of the Narrows outlet on the accession of the waters of Lake Iroquois through the Rome outlet, the lowering of the water-level from this cause, while the ice was retreating from the barrier south of Fort Edward to Street Road, can have been only a small part of the total change in water-level produced by the

cutting of the Narrows outlet. It would therefore follow that a large part of the 120–160-foot fall of water-level required in order to permit the emergence of the barrier south of Fort Edward was due to uplift, and the above remarks concerning the rate of the uplift and of the ice retreat would apply.

The correlation above assumed has the advantage of being in accord with the facts which suggest the existence of a Higher Glacial Lake George during the retreat of the ice from north of Glens Falls to near Street Road, and the disadvantage of permitting the formation of wave-wrought terraces at Street Road and Crown Point in Higher Glacial Lake Champlain in the approximate neighborhood of the ice under conditions which are cited below as causes preventing the formation of such terraces in the Hudson-Champlain water body.

*Second assumption.*—If the upper levels at Street Road and Crown Point be correlated with levels above the barrier south of Fort Edward, then the Street Road gravel plateau, the Crown Point high-level deposits, and a part of the upper series of wave-wrought terraces at these places were formed in the Hudson-Champlain water body. The absence in northern Champlain of the upper levels in the upper series of these wave-wrought terraces may be ascribed to the presence of ice here while they were being formed in southern Champlain. Under this assumption the demands made by the post-Higher Glacial Lake Champlain uplift at Street Road and Crown Point, will possibly permit the correlation (1) of the highest Street Road terrace with the 389-foot Glens Falls level, and (2) certainly with the 340-foot level. If the first correlation be correct, it is fatal to the hypothetical Higher Glacial Lake George; or if the Higher Glacial Lake George be real and not hypothetical, then its existence is fatal to the first correlation, and probably also to the correlation of the 340-foot Glens Falls delta with the Street Road and Crown Point levels, although it is barely possible that the latter correlation is permissible, even though the Higher Glacial Lake George did exist. If some terraces of the upper series at Street Road and Crown Point be thus assigned to the action of the Hudson-Champlain waters, then it follows that when Higher Glacial Lake Champlain was inaugurated the ice was as far south as the delta of the Bouquet River, where the

great range of the upper series of terraces has not been found. But if the ice was present on the Bouquet River when Higher Glacial Lake Champlain was inaugurated, there was time for the cutting down of the outlet as it retreated northward, and thus it would be expected that the terraces at the Bouquet River would have a greater range than northward where the uppermost wave-wrought terrace was not made until after the uppermost Bouquet terrace was completed. The failure of the terraces to show a greater range at this point (latitude of the delta on the Bouquet River) than farther north would indicate, either that the outlet was being cut very slowly, or that the water-level was being maintained at the north in some way, as the ice retreated from the Bouquet deltas. It is possible that uplift of the outlet maintained the water-level, or even caused it to rise in the northern part of the basin as the ice retreated, thus causing as great a range of terraces farther north as on the Bouquet River. The fact that the upper wave-wrought terrace near Whallonsburg is 30 feet higher than the surface of the Bouquet deltas would suggest that this tipping northward had been more than sufficient to overcome the effect of the cutting of the outlet as the ice was retreating, and that the water-level had actually been made to rise higher than its level when these deltas were made in the presence of the ice. If this explanation be correct, then at the south only, where the uplift of the outlet end of the basin could not maintain the water-level on the sides of the basin, would the range of the terraces be such as the cutting of the outlet alone would produce. Later, when the water-level began to fall throughout the basin, the ice had retired north of the Saranac River, and the range of terraces here seems to indicate that a differential northern uplift had begun.

*Another interpretation.*—The above has been written on the assumption that either the 580-foot Ausable, or the 640-foot Saranac gravel plateau, or both of them, are deltas made in the presence of the ice, and that the 500-foot Ausable and 520–540-foot Saranac deltas are the later product of erosion of the higher gravels. If it should be found that neither the 580-foot Ausable nor the 640-foot Saranac deposits are glacial deltas, but that the 500-foot Ausable and the 520–540-foot Saranac deltas are the highest, and if also some of the

more indistinct and uncertain terraces at Street Road and Crown Point be assumed not to be wave-wrought, then, because the wave-wrought terrace curve and the delta curve would be made to cross in the southern Champlain region, another succession of events must be assumed: After the ice had retired beyond the Saranac River, and after the 500-foot Ausable and the 520–540-foot Saranac deltas had been made in the Hudson-Champlain water body, the uplift at the south took place which inaugurated Higher Glacial Lake Champlain, and further uplift took place which tipped this water body into the northern end of the basin, causing it to rise to the level of the highest terrace in the upper series. The cutting of the outlet then permitted the upper series of terraces to be made.

On the whole it seems best to accept the reality of the upper terraces at Street Road and Crown Point, and to interpret these levels as in part Hudson-Champlain levels, and the lower part of this upper terrace series in the vicinity of Street Road and Crown Point and the entire upper series of terraces from the Bouquet River to north of the Saranac, as due to the waters of Higher Glacial Lake Champlain. While this may now seem to be the best interpretation, it certainly is not demonstrated.

### ALTITUDE OF THE HUDSON WATER BODY.

If the Hudson water body was a lake, its height above sea-level is indicated by three things: (1) elevation of the southern barrier at that time; (2) height above sea-level of Lake Iroquois, which drained into this Hudson water body through the Rome outlet; (3) the amount of change in elevation of the barrier since it emerged from the Hudson water body, and produced Higher Glacial Lake Champlain.

*Elevation above sea-level of the southern barrier.*—If the submerged extra-morainic Hudson channel was used at this time, as a part of the outlet valley, and if the Narrows channel was cut entirely as an outlet channel, then the land must have been higher than now by 122 feet plus the amount of the slope of the channel to the sea. With the large volume of water flowing through this valley, it may have been cut to a very gentle gradient, and the elevation of the Hudson water body above the sea-level may not have been more than 35–50 feet. It may have been much more.

*Evidence from the altitude of Lake Iroquois.*—Since this lake drained into the Hudson water body, it follows that the Hudson water body was lower than Lake Iroquois. The level of the latter has been calculated at about 200 feet.[1] It follows then that the Hudson water body was less than 200 feet above sea-level, by the amount of fall of the outlet stream from Lake Iroquois to the Hudson water body. If the lower delta of the Mohawk described by Professor A. P. Brigham at Schenectady (340 feet A. T.) was deposited by the Mohawk and not by streams of ice-water from the ice-front,[2] it would require an average slope of this outlet stream of less than 2½ feet per mile to permit the Hudson water body to be above sea-level.

*Amount of uplift of barrier south of Fort Edward since inauguration of Higher Glacial Lake Champlain.*—Since the barrier is now no more than 260 and no less than 220 feet A. T. it follows either that the Hudson water body was above sea-level when the barrier emerged from it, or, if it was at sea-level, there has been an uplift of 220–260 feet since the inauguration of Higher Glacial Lake Champlain. Since changes in the gradient of the outlet valley require an uplift of 60 feet or so, since the close of Higher Glacial Lake Champlain history,[3] it leaves an uplift of 160–200 feet to take place during the history of this lake. If there was this amount of uplift during this time, then the Hudson water body was at sea-level when the barrier which produced Higher Glacial Lake Champlain emerged from its waters.

## ORIGIN OF HUDSON WATER BODY.

There are two hypotheses to explain this water body.

1. (*a*) The water body was a lake made by a barrier at the south. (*b*) There was a succession of lakes made by a succession of barriers, or by a migrating barrier.

2. The water body was an arm of the sea.

Aside from the deposits made in its waters there are four series

[1] *Monograph 41*, U. S. Geological Survey, p. 775.

[2] *Bulletin of the Geological Society of America*, Vol. IX (1898), p. 205.

[3] This is based on the assumption that the valley at Whitehall has not changed in level and was 120 feet above sea-level when Higher Glacial Lake Champlain fell 120 feet to "Marine" Champlain level, and on a reasonable assumption as to the slope of this outlet valley.

of phenomena that must be accounted for in any explanation of the Hudson water body. They are: (1) the rise in level of the deltas and gravel plateaus northward; (2) the submerged channels, both in the lower Hudson and in the upper Hudson as far north as Troy; (3) the gap in the moraine at the Brooklyn Narrows, and the gap in the moraine at Perth Amboy, occupied by Arthur Kill (see Fig. 8, p. 426); (4) the scarcity of wave-wrought features.

1. *The rise of the gravel plateaus northward.*—Under either of the above hypotheses the land was relatively lower at the north during the presence of the water body than it is now, and there has been subsequent greater northern uplift. This greater northern uplift is necessary to account for the disappearance of the Hudson water body, if it was a lake, because the depth of the floor below the delta levels exceeds the known amount of the cutting of the outlet.

If the Hudson water body was a lake, the amount of northern uplift necessary to produce the present altitude of the deltas is greater than the amount necessary if they were formed in the sea, for the following reason: As the ice was retreating, the outlet was being lowered, so that the more northerly deltas must have been made at successively lower levels, unless there was some action to maintain the water-level. If the amount of cutting of the outlet be distributed among the sixteen or more different stands of the ice south of Street Road, it would cause but a small amount of fall between the successive stands. Even if the effect of the accession of the waters from Lake Iroquois by way of the Rome outlet be taken into consideration, and reasonable allowance be made for the increase in rate of cutting after that, it makes the fall in water-level between successive positions of the ice a comparatively small amount, much less than could be read from the topographic maps. Inequality in level of deltas due to this cause is much less than that due to unequal building up at the successive positions of the ice. In the aggregate, however, the amount of fall of water-level is considerable. If the cutting of the outlet during the history of the Hudson water body was 122 feet, it requires that the last delta made in this water body undergo an uplift of 122 feet more than would be required if they were all built in the sea at one stand of the land.

2. *Origin of the submerged channels.*—Under the first hypothesis

(the lake hypothesis) the land was not only relatively lower at the north than now, but at the south, from the beginning of the ice-retreat or soon after, it was higher than now. Its final altitude, however, before the recent submergence may not have been its altitude when the ice began its retreat. If the land at the south had its full altitude when the retreat of the ice began, then depression only is necessary here since then. If the full altitude was attained only after the ice had retreated some distance, the movement at the south was first one of uplift and finally one of depression. During the higher altitude, the channels, which are now under the waters of the Hudson estuary, were eroded and subsequent depression of the land has submerged them. Under the estuary or salt-water hypothesis the land was lower than now both north and south, when the gravel plateaus and other standing-water features were produced, and was subsequently uplifted; erosion produced the channels, and subsequent depression submerged them. Under either hypothesis, then, the retreat of the ice was followed by a time of higher altitude of land than now, and was succeeded by one of depression. The chief difference in the hypotheses is in the original altitude of the land and the time of uplift. According to the salt-water or estuarine hypothesis, the time of uplift was on the inauguration of Higher Glacial Lake Champlain, although the uplift may have been in progress in the southern Hudson before the emergence of the barrier in the northern Hudson that produced Higher Glacial Lake Champlain. The amount of this uplift before the disappearance of the Hudson water body is limited, however, by the levels which would give the sea access to the northern Hudson, if the water body was an arm of the sea. According to the lake hypothesis, the land was higher than now when the ice began its retreat, or soon after, and had either attained its full height then or did so during the retreat of the ice. According to either hypothesis, the full altitude of the southern Hudson had been attained before the close of Higher Glacial Lake Champlain history, and probably southern depression had begun.

3. *The gaps in the moraine.*—There are two gaps in the moraine between Brooklyn and Perth Amboy, the Narrows gap and the Arthur Kill gap (p. 426). The gap occupied by Arthur Kill has slopes which indicate that it may have been cut down from an elevation of from 25

to 40 feet above tide. The Narrows gap has steep slopes, which indicate that it may have been cut down from an elevation of 60 feet above tide. These estimates are not so reliable as they would be if the gaps were cut in a plain, because the moraine surface rises and falls, and a depression at a lower level than that indicated by the top of the steep valley side may have existed where these gaps now are.[1] However, it does not affect the results greatly whether the height of the barriers was a few feet more or less than the above estimates, but it is a matter of considerable importance to know whether the sea had access to the Hudson without an altitude of the land lower than the present, as the ice was retreating from the Brooklyn-Perth Amboy moraine. While it cannot be said to be demonstrable, the weight of the evidence seems to indicate that it did not.

According to the hypothesis that the Hudson water body was an estuary, these gaps must have been first scoured out when the land was enough lower to permit the sea to enter and the tide to scour. This requires a depression somewhat less, possibly, than 60 feet for the Narrows gap and 25–40 feet for the Arthur Kill gap. According to this hypothesis, tidal scour must have lowered these gaps to such an amount that, on the subsequent uplift which permitted the submerged channels to be carved out, either there was free passage for the streams that flowed through them, or they were scoured to a level lower than that of any other part of the barrier, and thus took off the drainage which finished the work of cutting away the barrier.

According to the hypothesis that the Hudson water body was a lake, these gaps were made by the outflow of fresh waters and not by tidal scour. This does not refer to the gaps at their present level, which may in part be due to tidal scour since the recent depression, but to their depth before the recent depression. If these gaps were cut by outflow of fresh waters, their relations are such as to require first a cutting as outlets of independent lakes, and later, when the ice had retired far enough to permit these independent water bodies to

[1] Professor Salisbury has suggested that these steep slopes may be due to recent wave-action. If this be the correct explanation, it makes the amount of cutting of the gap through the moraine even less certain. If, however, the overwash plain fronting the moraine was once continuous across the Narrows, as seems likely, the altitude of its inner margin (20–40 feet A. T.) marks the level from which the gap has been cut here.

coalesce, either (1) they did coalesce or (2) the outlets had been cut enough to so lower the water-level of each that they remained independent. If the lakes coalesced, then either (*a*) one of the outlets had been cut lower than the other, and thus rapidly drew off the water below the level of the other, or (*b*) both persisted and were rivals in the task of draining the lake.

In order that the requirements of the situation be clearly understood reference must be made to the maps showing the gaps and their relations to the present channels (see Fig. 8, p. 427, and Fig. 7, p. 425). From these maps it is observed that the Arthur Kill gap opens southward from Newark Bay, and that the Narrows gap opens southward from New York Bay. Newark Bay and New York Bay are connected by Kill van Kull ten miles north of Arthur Kill gap. New York Bay is connected with Long Island Sound by East River. The east end of Long Island Sound opens to the sea by wide channels. The land on the sides of both Kill van Kull and East River seems to indicate that the channels which they occupy have not been cut from much above sea-level. It follows, therefore, that if Arthur Kill and the Narrows gap were cut at first as outlets of independent lakes at the ice-front, and later as rival outlets of a water body that covered Newark Bay and New York Bay, they must either have been cut below the level of the divide between Long Island Sound and New York Bay before the ice retreated beyond it, or the present gap at the east end of Long Island must have been closed by a higher altitude of the land. Otherwise the Narrows gap at least would have been abandoned for a lower channel into Long Island Sound. While it is not at all unlikely that the gap at the east end of Long Island was closed, it is not essential for our present purpose to assume this. The writer, however, believes that the hypothesis that the present gap at the eastern end of Long Island was closed at that time by a greater altitude of the land is as tenable an hypothesis as any to account for the water body in which accumulated the recent clays of the Connecticut Valley and other valleys opening into Long Island Sound. It is in harmony with the published facts in regard to the distribution of those clays.[1] However, this is aside from the point under discussion.

[1] See N. S. SHALER, J. B. WOODWORTH, AND C. F. MARBUT, "Glacial Brick Clays of Rhode Island and Southeastern Massachusetts," *Seventeenth Annual Report*, U. S. Geological Survey (1895–96), pp. 957–1004.

If the Narrows gap and Arthur Kill gap were started as outlets of independent lakes at the ice-front, then by the time the ice had retreated far enough to permit these water bodies to coalesce, either both had been cut below the divide now crossed by Kill van Kull, and had thus produced independent water bodies in Newark Bay and New York Bay, or they became rival outlets to a common water body. If they became rivals, then one of the following things happened: One of them drew off the water below the level of the other, or before either one was victorious both had succeeded in cutting below the level of the land along Kill van Kull, and thus produced independent water bodies (in Newark Bay and New York Bay). If one was victorious, the Narrows gap, since it finally became the deeper, presumably was the one. Under this interpretation the Newark Bay Lake became tributary to Hudson Lake. Arthur Kill may have remained, however, the channel of the Rahway-Woodbridge Creek system (see Fig. 8), and thus have been deepened more. In either event, the Newark Bay water body became independent and drained either through Arthur Kill or by way of Kill van Kull. The deposits in the lowlands west of the Palisade Ridge were made in this independent water body. If Arthur Kill remained the outlet, then the present Kill van Kull channel is due either to tidal scour or to the work of a tributary working back from the Hudson, or to both. If Arthur Kill was abandoned, and Kill van Kull was the outlet of this Newark Bay Lake, the present channel is due to cutting by the outflow of its waters and to subsequent tidal scour, and Arthur Kill gap is due partly to cutting as an outlet of a lake, and later to cutting by the Rahway-Woodbridge Creek, and no doubt also to some recent tidal scour.

If the present channels be accepted as inheritances from the past, and not due to tidal scour, or at least not enough to obscure their former relations, it would seem that the Hackensack-Passaic system, along with Elizabeth River, finally became tributary to the Hudson through Kill van Kull on the disappearance of Newark Bay Lake, and that the Rahway River with Woodbridge Creek formed a system flowing through the Arthur Kill gap. If the submerged channel outside the moraine near Princess Bay Light, likewise is an inheritance from the past and not due wholly to tidal scour, the Rahway-Woodbridge

system was tributary to the Raritan, which, presumably, was tributary to the Hudson. The connection of the submerged Raritan and extra-morainic Hudson channel, however, cannot now be traced.

4. *Scarcity of wave-wrought features in the Hudson Valley.*—The almost complete absence of wave-wrought terraces in the area of the Hudson water body south of Glens Falls is not what would be expected. Even faintly developed terraces have been observed at a few places only. This apparent lack of effective wave-action may be due to the following:

(1) In the presence of the ice-sheet the water body was frozen over for considerable periods of the year, and during the summer season the presence of floating ice would tend to reduce the effectiveness of the wind in producing waves. This explanation would apply on either hypothesis for the origin of the Hudson water body. It would be more applicable if the body was a lake, but would apply if the water body was the sea, and if much freshened as suggested below (p. 650), it would be nearly on a par with the action in a lake.

(2) After the ice-sheet had retired to the northern part of the area, these conditions would no longer exist or would be much weakened in their effect and wave-action would be expected. (*a*) It is to be noted here, however, that the southern part of the area is the narrow part where the wind would have comparatively little chance to produce effective waves, even under the most favorable conditions of temperature. The greater width of the water body in the northern part of the Hudson would seem to necessitate effective wave-action after the ice retired into the Lake Champlain region and the climate had become warmer, so that the surface was no longer frozen over for so large a part of the year. Too much emphasis, however, must not be placed on the warming up of the climate, for boreal willows in the Salmon River section indicate a climate considerably colder than the present in Marine Champlain time. (*b*) It is to be noted, also, that this wide northern part of the Hudson water body was divided into smaller portions by numerous islands and shoals (see Fig. 13, p. 437), and these would decrease the efficiency of the wind in producing waves. (*c*) If this water body disappeared shortly after the ice had reached the Champlain valley, the length of time for this effective wave-action was reduced, and the earlier the dis-

appearance the more applicable the explanation becomes. If the Hudson water body existed until the ice had retired to the Bouquet River, or beyond the Saranac, as is considered in the various hypotheses stated for the time of origin of the Higher Glacial Lake Champlain, then there was a long time for the production of shore terraces. The time necessary to make the secondary deltas noted on the Batten Kill and the Hudson River would seem to be ample for the development of distinct wave-wrought terraces, and it is in this part of the valley only that features have been observed that may be assigned to wave-action, but it is surprising that they are not better developed here. (*d*) There is evidence that the water-level was not constant. Possibly there were two things to make it inconstant: first, the cutting of the outlet, and, second, crustal movement. The first could be true, of course, only if the Hudson water body was a lake. The second could be true under either hypothesis for the origin of the water body, and, as mentioned above, is necessary for the disappearance of the water body under either hypothesis.

Altogether the slight development of wave-wrought features in the Hudson is unexpected, and the above explanations do not seem to be wholly satisfactory, especially when it is recalled that under apparently very similar conditions distinct wave-wrought features were made in the Champlain region. The writer is forced to believe that a more detailed examination of the Hudson region will bring to light more evidence of wave-action.

*Features unexplained by the salt-water hypothesis.*—Certain features are present which are in accord with the lake hypothesis, but not with the salt-water hypothesis. There are certain features not present which seem to be required by the latter hypothesis, but not by the former. If the Hudson water body was an arm of the sea, the presence of some of these features and the absence of others must be accounted for. These features are: (1) absence of distinct wave-wrought features at the outer edge of the Brooklyn-Perth Amboy moraine at the levels required by the hypothesis; (2) presence of the overwash plain on Staten Island and Long Island without distinct features to be ascribed to wave-action; (3) entire absence of life certainly marine in the deposits made in the Hudson water body; (4) apparent absence of tidal distribution of muds in the Hudson

water body; (5) evidence of the altitude above sea-level of the Hudson water body.

1. Absence of distinct wave-wrought features at the outer edge of Brooklyn-Perth Amboy moraine.—There is an absence of wave-wrought features of a decisive character outside of the moraine in a region where the materials are soft and easily washed and which must have been exposed to strong waves from the Atlantic. Although these materials are displayed with a topography which would not offer the best opportunity for effective wave-action, yet it seems incredible that the sea could have been present over the area outside of the moraine, at the levels demanded by the gaps in the moraine and for the time necessary for the tide to scour out these gaps to the required depth, without leaving a decisive record in the easily eroded drift. Three suggestions aiming at an explanation of this are as follows: (*a*) That these gaps were first made by the wearing of ice-waters before depression took place, and were subsequently deepened by tidal scour when the land had been depressed enough to admit the sea. If this be admitted, the same early conditions as those under the lake hypothesis are assumed, the main difference being in the time of depression and in the number of depressions. (*b*) That ice protected the shore from wave-action. This would seem plausible for the time when, and the places where, the ice was present, but is difficult of acceptance after the ice-edge had retreated. Shore-ice might, however, have remained for long periods of the year, after the ice-sheet had retreated. (*c*) The land rose rapidly after the original depression, thus preventing the making of a distinct record of wave-action. If this was so, equally rapid scouring of the channels must be postulated in order to acccount for the access of the sea to the Hudson Valley. It is doubtful if the rapid rise would be effective unless the movement was very rapid, and then the scouring would be handicapped.

2. Presence of the overwash plains at the ice-front.—The presence of the overwash plains at the ice-front on Long Island and Staten Island without distinct features to be ascribed to wave-action, or a form that the presence of the sea over them would lead one to expect, argues strongly for an altitude of land above sea-level when the overwash plain was building. If the submergence hypothesis is tenable, it would seem necessary, as above, to postulate an altitude of land at

least as high as the present when these overwash plains were made, and higher than that when the gaps in the moraine were being cut, with enough subsequent depression to give the sea access, thus forming the Hudson water body. Such a crustal movement is the opposite of what would be expected as the ice retreats.

3. Absence of life certainly marine.—The only fossils that have been found in deposits in the Hudson water body are: (1) sponge spicules, fresh-water diatoms,[1] and worm tracks at Croton; and (2) leaves of *Vaccinia oxycoccus* at Albany.[1] No marine fossils have been found, unless the sponge spicules are such, and their identifica-cation, it seems, is uncertain. The presence of fresh-water diatoms is not necessarily fatal to the hypothesis of a salt Hudson water body, for they may have been brought into the salt water by the streams and deposited with the sediments in the salt water. If the sponge spicules are those of salt-water sponges, and if they were found in clays which antedate the recent depression, they settle the question of the origin of the Hudson water body.[2] Although there is an entire absence of life certainly marine in the deposits of this time throughout the entire stretch of 240–265 and possibly more than 300 miles through which the Hudson-Champlain water body extended (see Fig. 22), in the northern portion of the same region there is abundant evidence at low levels of marine life, which came up the St. Lawrence after the Hudson-Champlain water body had disappeared. Unless there is a sufficient explanation, this must be admitted as a strong argument against the salt-water hypothesis. However, it must be admitted that there is likewise a paucity of any forms of life in the Pleistocene deposits of the Hudson Valley. In explanation of the absence of marine life in this hypothetical long arm of the sea three

[1] See footnotes 3 and 4, p. 454.

[2] These sponge spicules were reported from Croton by Mr. Heinrich Ries in 1895. Since the above was written and first placed in the hands of the printer, word has been received from Mr. Ries that the sponge spicules are those of species not confined to salt water. The exact locality at Croton from which the specimens came is also a matter of some uncertainty. That they came from 20 feet below sea-level and were found in solid lumps of clay is certain, however. Inasmuch as some of the clay used at Croton for brick-making has accumulated in the Hudson estuary since the recent depression, it is possible that the clay in which these specimens were found was deposited long after the disappearance of the Hudson water body, and that therefore the fossils mentioned have no bearing on the origin of the Hudson water body.

suggestions have been made: (1) The waters were cold while the ice was near. (2) The waters were muddy while the ice was near. (3) The waters were freshened because of the great territory—at one time the Great Lakes drainage basin—drained into this water body, and because of the shallow sill over which little salt water could pass.

(1) In regard to the first suggestion it may be said that the waters were cold, but they were decreasingly cold as the ice retreated 240–300 miles and more northward. In Greenland, at the present time, marine life is abundant in the waters close to the ice-edge,[1] so that even if the waters were cold it does not appear to be a sufficient reason for the absence of salt-water life. Further than this, marine life invaded the Champlain region soon after the ice had retreated across the St. Lawrence and permitted the sea to enter. The fact that it failed to do so during the much longer time it had to get into the Hudson from the south while the ice was retreating northward argues strongly against the salt-water hypothesis.

(2) The waters were muddy. This argument would hold good so long as the ice was near. When at a greater distance, the argument does not hold good, for it seems to be true that there was comparatively little deposition of muds at a distance from the ice. Were it not so, the kames and other ice-molded forms at low levels would have been buried. The presence of marine life in the clays on the coast of Maine, and also in somewhat younger clays in the Lake Champlain region, indicates that marine life could exist while the deposition of considerable fine sediment was taking place. The explanation of the absence of life because of the muddiness of the waters therefore does not carry conviction with it, especially since there was so much opportunity for the introduction of life after the ice had retreated a great distance and the waters had become clear.

(3) The water was kept fresh because of the shallow sills over which the salt water had little access. This is perhaps the best explanation offered.[2] It necessitates a higher altitude at the east end of Long Island Sound than the present; otherwise there would

[1] Verbal communication of Professor Chamberlin. See also R. D. SALISBURY, *Glacial Geology of New Jersey*, p. 513.

[2] See R. D. SALISBURY, *Glacial Geology of New Jersey*, Final Report of the State Geologist, Vol. V, pp. 511–13.

have been abundant opportunity for life to come into the Hudson over the low land between Long Island Sound and the Hudson, and the Connecticut Valley deposits, which appear to resemble those of the Hudson in many respects would be expected to show abundant marine life.

It may be said, however, that this argument of shallow water over the sills has its limitations. It has been shown that it is necessary to believe that the channels through the moraine were cut down a considerable amount before the Hudson water body disappeared. On the submergence hypothesis tidal scour must be relied on to do this cutting, and reduction of the amount of water to get in over the sills at high tide reduces the amount that could go out with the ebb, and thereby proportionally reduces the efficiency of scour; and if none comes in, the scouring is reduced to the action of the fresh water supplied by the streams. This limitation would be more severe in Newark Bay perhaps than in the Hudson, where the great amount of fresh water flowing from Lake Iroquois into the Hudson waters after the Rome outlet came into use would be available for scouring the channel. The argument would not apply so well, however, in explanation of the absence of marine life in the Connecticut Valley. The demands of later events require a scouring out of the Hudson channel at the narrows to a considerable depth—possibly as much as 122 feet—before the Hudson water body disappeared. It would seem that this amount of scour would admit plenty of salt water and marine life. It may be, however, that water in the scoured channel was kept shallow by uplift, and the supply of salt water was thereby limited. Altogether it would seem possible that the explanation offered might account for the absence of marine life in the Hudson, if the delicate adjustment required to keep the water shallow over the sills existed. It is not known, however, that the conditions postulated actually did exist. The explanation would not apply to the phenomena in Long Island Sound, and in the Connecticut Valley, if the altitude of the land was as low as at present. It is doubtful if it is adequate even for the Hudson Valley phenomena without a higher altitude of land at the east end of Long Island Sound. This higher altitude is a requirement of the same kind, and nearly as great, as for the lake hypothesis in both the Hudson and Connecticut Valleys, and

greater than required for the Hudson Lake alone, which could have existed without this eastern uplift.

4. A fourth argument against the salt-water body is the absence of tidal action indicated by the fact that fine sediments were apparently not carried to any great distance from the ice-front. This is shown by a failure to bury some of the kames and other ice-molded features at low levels adjacent to higher gravel, sand, and clay. It may be said that this apparent failure of the fine sediments to be carried out on older and lower deposits in some situations, especially in the southern Hudson, is so extraordinary as to tax even the lake hypothesis. In some places this may be explained, however, by the persistence of protective stagnant ice-masses. There may be a question whether stagnant ice-masses would endure long enough to be thus effective. If there was sufficient tidal scour to cut the gaps in the moraine the amount required by later events, it is a question if the ice-masses could have endured long enough to prevent the burying of the kames, etc., by the finer sediments carried by the tide.

5. A fifth point bearing on the hypothesis that the Hudson water body was an arm of the sea is the evidence presented by its altitude when Higher Glacial Lake Champlain was separated from it. The evidence goes to show that its altitude at this time was something less than 200 feet above tide. How much less is unknown. If the amount of uplift while Higher Glacial Lake Champlain was being drained could be determined, the altitude of the Hudson water body when the barrier south of Fort Edward appeared would follow. (See pp. 639, 640.)

## WHAT EVIDENCE IS THERE THAT THE HUDSON WATER BODY WAS A LAKE?

If the existence of a body of standing water be admitted, all the arguments against the submergence or salt-water hypothesis throw the scales in favor of the lake hypothesis. The evidence in favor of the lake hypothesis is as follows: (1) the existence of a barrier; (2) the evidence of deep channels cut through that barrier and submerged channels of drainage both inside and outside the barrier; (3, 4, 5, 6, 7) the five points mentioned above, as opposed to the salt-water hypothesis.

1. *The existence of a barrier makes the lake possible.*—Under the

sea hypothesis it also makes it necessary to explain the gaps in the barrier as, in part at least, due to tidal scour—an action which may have been limited (see the explanation for the absence of marine fossils as due to the shallowness of the water over the sills giving access to the salt water, p. 651). A barrier at the east end of Long Island Sound is not necessary for the existence of Lake Hudson, but an altitude of the land higher than now in that region is required by the supplementary explanation attached in this article to the salt-water hypothesis, and an altitude but little greater would produce a lake, and thus bring the Connecticut Valley phenomena and Hudson Valley phenomena under one explanation. It is not meant to imply here, however, that the Hudson and Connecticut water bodies were one water body. It seems certain that, if they were at an early date, they became independent later.

2. *The channels through the barrier and the submerged channels inside and outside the barrier.*—Under the lake hypothesis the outlet valley was a necessary feature, and the submerged channels are the natural consequences of the drainage of the lake, subsequent erosion by the Hudson, and later depression. Under the salt-water hypothesis the gaps must be explained as due to tidal scour which extended to a depth great enough to let the streams flow through them when elevation had taken place, but the completion of the channels was by the erosion of the Hudson at the subsequent higher stand of the land and perhaps by recent tidal scour. The lake hypothesis makes the gaps and extra-morainic channels now submerged, contemporaneous, in part at least, with the existence of the lake. The salt-water hypothesis makes them due in part to tidal scour, and in part to erosion following the uplift of the land and the consequent recession of the sea.

The channels inside the moraine in Newark Bay may be contemporaneous with the later history of the Hudson Lake. Under the salt-water hypothesis they follow uplift, but may be contemporaneous with deltas in the upper Hudson. The fact that the disappearance of the Newark Bay water body followed an uplift of the land of just about the amount necessary to cause this water body to disappear favors the submergence hypothesis (see p. 657).

ARGUMENTS OPPOSED TO THE HUDSON LAKE HYPOTHESIS.

There are two possible arguments against the lake hypothesis. One of them is based on the altitude of land farther south in New Jersey. Certain terraces on the south shore of Raritan Bay and south form in part the basis for belief in the lower altitude of land in that part of New Jersey, but such terraces are not found on the drift-covered north side of Raritan Bay.[1] This would indicate that the submergence which produced the terraces on the south side of Raritan Bay came earlier, and that, if it extended to the north side, emergence had taken place before the ice retired. Professor Salisbury assigns the date of the submergence which produced these terraces either to late glacial or post-glacial time,[2] but he considers the question of submergence in the vicinity of New York as still an open one.[3] The absence of distinct wave-wrought features on the Brooklyn-Perth Amboy moraine and on the overwash plain between Brooklyn and Perth Amboy does not favor the hypothesis of submergence there, and it is difficult to reconcile the absence of these features with the hypothesis of a lower altitude of land.

There is another objection to the lake hypothesis which, if it were valid, would argue for the salt-water hypothesis. It is that the southern barrier could not have lasted during the great time it took to make the clays in the region north of the moraine. As will be seen from the discussion of the origin of the gaps in the moraine, if the barrier consisted of the moraine only, and was limited to that part of the moraine above present sea-level, it must be admitted at once. It must be remembered, however, that at the time of maximum southern elevation the outlet stream was cutting through a wide stretch of land outside the moraine. As mentioned before, the shore line of this time may have been 95–100 miles farther south. It is very likely, also, that the outlet was never very high above sea-level, but that the uplift was taking place while the ice was retreating, so that the rate of cutting of the barrier would be kept close to a minimum. It must be remembered also that the character of the lower portions of the channels through the moraine is unknown. It may well be

[1] G. N. Knapp, verbal communication.

[2] *Glacial Geology of New Jersey*, p. 204.

[3] See *New York City Folio*, U. S. Geological Survey, p. 16.

that it is of such a nature as to resist erosion. It would be expected, indeed, that after a certain amount of erosion of the moraine the concentration of the larger bowlders which are common in moraines would form a pavement in the bottom of the channel and would check the down-cutting.

FIG. 27.—New York and vicinity as it would appear if depressed enough to permit the entrance of the sea over the probable original height of the barrier at the Narrows and at Perth Amboy, and if the depression south of the Raritan River were forty to fifty feet.

Black color indicates land not covered by waters during the hypothetical depression. The outline represents the present coast.

In conclusion, it may be stated that, while no single argument seems to be fatal to the salt-water hypothesis accounting for the

Hudson water body, unless those drawn from the phenomena on the outside of the moraine be such, it is likewise true that the facts are not fatal to the lake hypothesis, unless the sponge spicules reported from Croton represent salt-water species.[1] Aside from these sponge spicules, the weight of the evidence seems to be in favor of the lake hypothesis.

### RELATION OF HUDSON WATER BODY TO THE CONNECTICUT VALLEY WATER BODY.

If the Hudson water body was an arm of the sea, there is no need of discussing the relation between the Connecticut Valley deposits and those of the Hudson more fully than they have already been discussed. It is enough to repeat here, what has been said before (p. 651), that in order to account for the absence of life certainly marine in the Hudson, on the hypothesis stated above (p. 650), it seems necessary to postulate a higher altitude of the land at that time at the east end of Long Island Sound, so as to shut out free access of salt water to both the Connecticut Valley and the Hudson Valley.

If the Hudson water body was a lake, it does not necessarily follow, of course, that the Connecticut Valley deposits accumulated in a lake. This explanation is given for these deposits in Massachusetts.[2] It is true nevertheless that a southern uplift somewhat more than that necessary to make Hudson Lake would equally well account for the phenomena of the Connecticut Valley. So far as published accounts indicate, there is little, if any, clay of late glacial age, outside of the area north of Long Island Sound, which could not be explained as having accumulated either in local lake basins, or in the sea when the land at the north was depressed enough to submerge the clay areas along the eastern New England coast. This northern depression is not incompatible with the southern uplift which would produce a lake in Long Island Sound and in the valleys and lowlands north of it. If Long Island and the land to the east were high enough to make a lake north of it, either from the start or later on, this water body was divided into several parts.

[1] See footnote, p. 649.

[2] See EMERSON, *Monograph XXIX*, U. S. Geological Survey, Chap. 19.

RELATION OF HUDSON WATER BODY TO WATER BODY WEST OF PALISADE RIDGE.

As already indicated, if the Hudson water body was an arm of the sea, so also were the waters in the lowland west of the Palisade Ridge by the time the ice had retired beyond the Sparkill Valley or earlier. If the Hudson water body was a lake, the waters west of the Palisade Ridge,[1] which may be called Newark Bay Lake, were probably independent while the ice was present and either drained through Arthur Kill, or first through that outlet and later into the Hudson by Kill van Kull. This Newark Bay Lake, no doubt, disappeared long before the Hudson Lake. It is interesting to note that when the ice had retreated beyond the Sparkill Valley, which crosses the Palisade Ridge just north of the New Jersey boundary (Fig. 9, No. 14, p. 429), the waters of this Newark Bay water body coalesced with those of the Hudson water body through this narrow valley, the bottom of which is now 20–30 feet above tide at the west side of the Palisade Ridge. Since the land was at this time down at the north by 75–90 feet more than at the south, it follows that this Sparkill Valley was the lower outlet, and that when the Hudson water body had been lowered to the level of this valley, the Newark Bay water body disappeared. Whatever cutting, therefore, was done at a southern outlet was accomplished before the ice had retired beyond this valley. It is likewise interesting to note that with this amount of northern depression the slope of the Hackensack Valley floor, for instance, would have been just the reverse of the present. If, when the water body disappeared this was true, the lower Hackensack, for instance, and other streams would have flowed in the reverse of their present direction and joined the Hudson water body through the Sparkill Valley. Since there is no evidence, so far as the writer is aware, that such a reversal has taken place, it would follow that by the time the Hudson water body disappeared there had been an uplift sufficient to produce a slope southward. That uplift must have been as much as 45–60 feet, and may have been more. Since the water-level must have been lowered this same amount in order to disclose the floor, it would seem that the disappearance of the water in this area was due to uplift. This

[1] For discussion of hypotheses to account for this water body see R. D. SALISBURY, *Glacial Geology of New Jersey*, pp. 195–200.

may have been true under either origin of the water body, and must have been true under the estuarine hypothesis. The early history of this water body was in part contemporaneous with that of Lake Passaic,[1] but the latter lake had disappeared before the Newark Bay water body had attained its greatest dimensions. When the Newark Bay water body disappeared, the floor was exposed as a broad stretch of plain partly covered with sand, through which the Passaic-Hackensack River took its course and was joined east of Shooter's Island by the extended course of Elizabeth River. From the sands of this Newark Bay lake-floor the dunes which occur on the west side of Newark Bay at various places were made.[2] If the peat under this sand is a salt marsh accumulation, as Professor George H. Cook thought, the interpretation must be altered accordingly.

## RELATION OF HUDSON WATER BODY TO LAKE IROQUOIS.

The delta of the Mohawk River in the Hudson water body is reported at 340 feet above tide.[3] If this was made at a time when Lake Iroquois was draining out through the Rome outlet, it shows that the Hudson water body had a level lower than Lake Iroquois, by an amount, however, not necessarily the same as the present difference between the Lake Iroquois level and the delta level.

If Higher Glacial Lake Champlain was inaugurated before the ice retired beyond the Adirondacks, then here is the only opportunity to determine the relation between the levels of Lake Iroquois and the Hudson or Hudson-Champlain water body. If Higher Glacial Lake Champlain was not inaugurated until after the ice retired beyond the Adirondacks, then the waters of Lake Iroquois must have fallen to the level of Hudson-Champlain, and subsequently had the same level as that of Higher Glacial Lake Champlain on the uplift of the barrier south of Fort Edward. The weight of the evidence, however, is against this succession of events.

[1] See ROLLIN D. SALISBURY AND HENRY B. KUMMEL, "Lake Passaic: An Extinct Glacial Lake," *Annual Report of the State Geologist of New Jersey* for 1893, pp. 225–328.

[2] See *Geology of New Jersey*, 1868, p. 228, and *Annual Report of New Jersey State Geologist*, 1893, p. 205.

[3] A. P. BRIGHAM.

RELATION OF HIGHER GLACIAL LAKE CHAMPLAIN TO IROQUOIS.

Lake Iroquois was made by the ice blocking the St. Lawrence and causing the waters in the Ontario basin to overflow at the lowest point of the basin which was then near Rome, N. Y. During the retreat of the ice a differential uplift was in progress greater at the north. G. K. Gilbert says that when the Rome outlet (present level, 440 feet above tide) was abandoned at the close of the Iroquois epoch, "the water of the Ontario basin descended for a time along a course beginning near Covey Hill, and ending near West Chazy, N. Y."[1] Whether these levels are marked by shore terraces is not stated. If they are, it would seem that when the ice retired far enough north in the Champlain Valley, the waters of the Ontario and Champlain basins coalesced. This water body might properly be called Lake St. Lawrence—a name suggested by Upham in 1895.[2] If these levels are not marked by shore terraces, but simply by a series of outlet levels,[3] then it would seem that the waters of Higher Glacial Lake Champlain and the successor to Lake Iroquois did not coalesce, at any rate not until the close of Higher Glacial Lake Champlain time, when both fell to the levels which have been called "Marine" Champlain levels although the highest of these levels do not seem to contain marine fossils (see p. 626).

During "Marine" Champlain time these waters not only occupied the Champlain Valley, but extended into the Ontario basin, as is shown by the fact that the "marine" shores of the Champlain Valley extend westward through northern New York to the Ontario basin, being continuous with the so-called Oswego shore line.[4] In the Ontario basin as in the Champlain basin there is evidence of differential uplift greater at the north, in the late stages of the ice-retreat.

DURATION OF HUDSON WATER BODY.

If the Brooklyn-Perth Amboy moraine be correlated with the earliest Late Wisconsin terminal moraine, the history of the Hudson

[1] *Eighteenth Annual Report*, U. S. Geological Survey, Vol. I, p. 59.

[2] See *American Journal of Science*, Vol. CXLIX (1895), pp. 1–18; *Monograph XXV*, U. S. Geological Survey, p. 264. See also this article, p. 626.

[3] Since this was written and placed in the hands of the printer the writer has learned from conversation with Mr. Gilbert that this is the fact.

[4] G. K. GILBERT, *loc. cit.*

water body spans, or more than spans, the history of the entire system of moraines of that time represented in Ohio, Indiana, and Illinois. In terms of the history of the succession of the Great Lakes, it spans or more than spans, the history of Lakes Maumee, Whittlesey, Warren, Dana, and part of Iroquois,[1] and possibly all of the latter, according to the interpretation of the time of inauguration of Higher Glacial Lake Champlain. In terms of the history of Lake Chicago, it began earlier, and whether it ended earlier or later depends on the time the northern outlet of Lake Chicago was opened up by the retreat of the ice.

### TIME DIVISIONS.

If the beginning of the retreat of the ice from the Brooklyn-Perth Amboy moraine be counted as Champlain time, then the time since the moraine was made may be divided as follows:

1. Hudson-Champlain.
2. Higher Glacial Lake Champlain.
3. "Marine" Champlain.
4. Present Lake Champlain.

Possibly the upper part of the levels marked "Marine" Champlain may represent another lake named by Upham Lake St. Lawrence, and thus make another division.

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[1] For an account of the history and relations of these lakes see LEVERETT, *Monograph* 41, U. S. Geological Survey, pp. 710-75.